The Development of Guidelines for Very Large Floating Structures

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ABSTRACT

Because of the high-grade functions they possess, very large floating rate structures (VLFS) that float on the ocean have numerous possibilities as structural bases for the 21st century. Such structures will suffer almost no effects from large-scale earthquakes that would inflict heavy damage on land-based structures. In addition they are environment-friendly. Because VLFS will float on the ocean surface, their impact on the natural environment will be comparatively small and it willremain possible to restore the natural environment to its original condition as necessary.

These structures are thought to have many possible uses in the future as distribution bases, floating airports, sea-based cities or facilities that can be used in the event of disasters.

VLFS are envisioned as being utilized for multiple purposes for extended periods of time by vast numbers of people, filling important social functions as distribution centers, airports, cities, or disaster facilities. Therefore, preparations to ensure the safety of such structures, based upon adequate consideration of existing structural analysis techniques, the characteristics possessed by the structures, and accumulated knowledge regarding ocean and weather conditions, are of utmost importance. In addition, VLFS will be stationed at specific ocean place and will have to include all of the structures or facilities needed to fulfill the multiple purposes for which they will be used as described above. In order to provide access for individuals using VLFS, VLFS will also have to be combined with some means of transportation such as ships or with transportation facilities such as bridges or tunnels. Depending upon the location, breakwaters may be required as well. Because VLFS will be integrated from many of these types of structures and facilities as shown in fig.1, the effects of these related structures or facilities must also be carefully considered to ensure the safety of the VLFS.

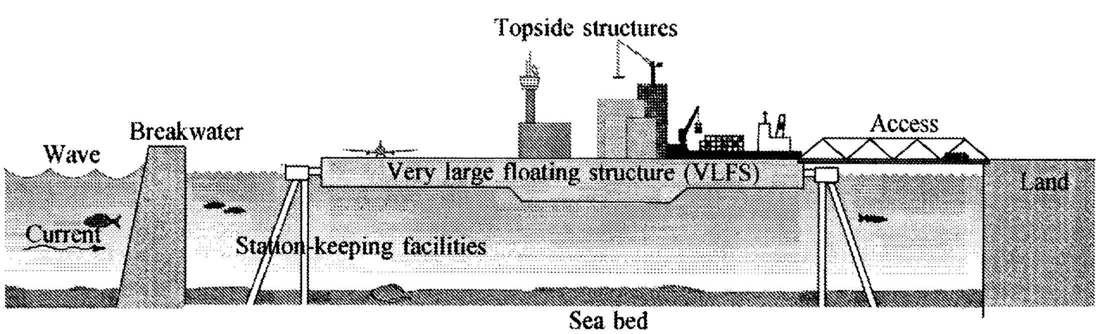

Fig.1 Artificial Floating Base

Accordingly, the need to stipulate standards and follow appropriate safety inspections based upon those standards must be addressed in order to ensure the adequate safety of VLFS as integrated systems, earn the broad support of society, and allow comfortable and practical application of these unprecedented ocean-based structures by the general population. Such standards and safety inspections will be an important prerequisite to the practical application of VLFS.

With this understanding in mind, the Coastal Development Institute of Technology (CDIT) has collaborated with the Technological Research Association of Mega-Float (TRAM) on a development of safety guidelines for VFLS in the fiscal year 1996 to 1998. A summary of these guidelines is provided below.

1. OBJECTIVES OF THE RESEARCH

VLFS will satisfy their designated functions through various facilities constructed on their upper surface that required to fulfill the VFLS utilization objectives (referred to below as "topside structures") and other accompanying facilities erected in the near by vicinity. Our research was conducted by focusing on the safety evaluation for VFLS on which topside structure can safety be erected. VFLS are structures that possess the following characteristics.

(1) They surpass the size of the largest existing ocean-based structures.
(2) They possess elastic properties based upon the aspect ratio (example: length/depth, etc.) of the structure.
(3) They can be used over a long period of time (for example, 100 years).
(4) They must be assembled at sea.

In order to appropriately evaluate the safety of VLFS, guidelines of some nature that reflect these VLFS characteristics and a precise understanding of factors such as external natural forces acting on VLFS and their structural characteristics are required. It was therefore determined that surveys and research concerning safety design, approaches to safety evaluation, and evaluation techniques for VFLS were needed and that a safety guidelines for VFLS should be developed. It will be drafted guidelines to address all of alternatives such as airports, distribution facilities, and emergency locations based on the guidelines for VFLS

2. RESEARCH SYSTEM

To ensure that the research progressed smoothly, a Safety Standards Investigation Committee (Chaired by professor Kouichiro Yoshida of University of Tokyo) composed of individuals with knowledge in shipbuilding, general construction, ports and harbors civil engineering, steel manufacturing and the environment was established, together with a Safety Standards Investigation Specialist Sub-Committee. Working groups were also created to specifically draft the standards proposals. The research system is shown in Fig. 2.

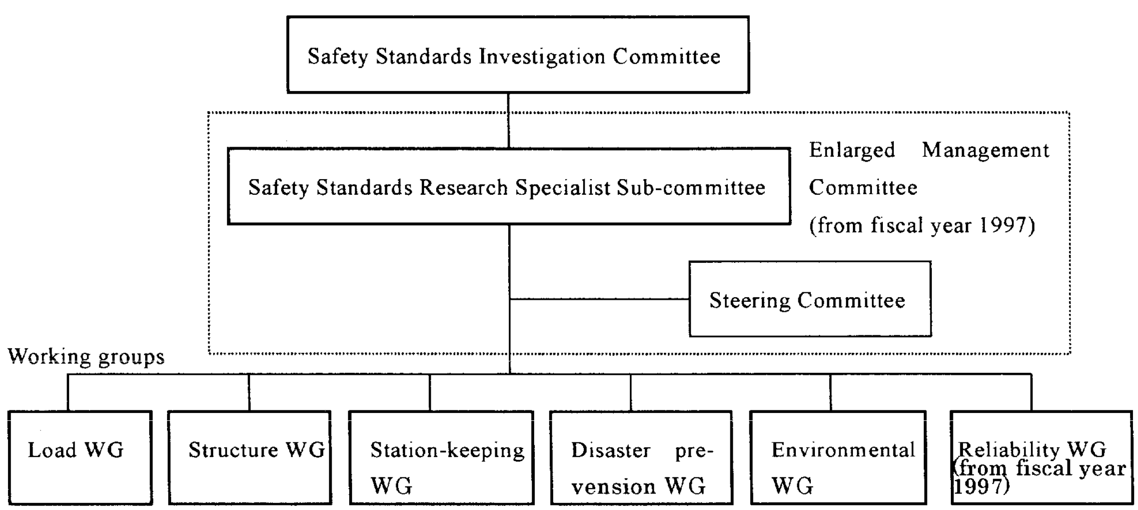

Fig.2 Research System

3. SUMMARY OF THE SAFETY GUIDELINES FOR VLFS

3.1 Organization of the guidelines

The guidelines differ from the standards for shipbuilding, structures, and civil engineering structures on two points. The first is that the effects exerted by the structure's presence on the surrounding environment cannot be ignored because of the enormous size of the structures being considered and because such structures will be used for extended periods of time. When planning to locate these kinds of structures in certain ocean regions, an evaluation regarding the structures' effect on the environment must be undertaken before other considerations. The second difference is that the structures being considered will consist of a floating structure, station-keeping facilities, topside structures, transportation facilities to land such as bridges or tunnels, and waves and currents control facilities such as breakwaters that will have to be erected as required. Therefore, careful consideration needs to be given to the mutual influences of these structures on each other as an integrated system. In light of these considerations the standards proposals have been organized as follows.

(1) Chapter 1 General provisions
(2) Chapter 2 Environmental impact assessment
(3) Chapter 3 Materials
(4) Chapter 4 Design loads
(5) Chapter 5 Floating structures
(6) Chapter 6 Station-keeping facilities
(7) Chapter 7 Waves and current control facilities
(8) Chapter 8 Disaster countermeasures
(9) Chapter 9 Construction quality control
(10) Chapter 10 Maintenance
(11) Chapter 11 Overall assessment

A summary of each chapter is provided below.

3.2 Summary

A brief summary is presented below outlining the content of each chapter of the proposals.

3.2.1 Chapter 1 General provisions

(1) Definition of "Artificial Floating Base"

The term "very large floating structure" used by research institutions refers to floating structures that are built in order to make effective use of promising ocean spaces. The uses of these engineered structures will vary depending upon the placement of facilities having designated functions either on top of ("topside") or within the structure. More specifically, however, the term "very large floating structures" is used to mean an integrated structural system consisting of a floating structure and station-keeping facilities to maintain the structure's position, facilities or structures erected topside that are suited for the designated use of the floating structure, wave and current control facilities such as breakwaters erected when required by wave conditions in the ocean zone where the floating structure will be located, and means of access such as bridges or tunnels to enable people and vehicles to move freely between land and the floating structure. Because the term "structure" conveys the meaning of ordinary, simple engineered structures, however, for the purpose of these proposals the expression "artificial floating base" was coined from the term "artificial base" used in the construction sector and is used to specify these structural systems. The organization of these structural systems is shown in Fig. 3.

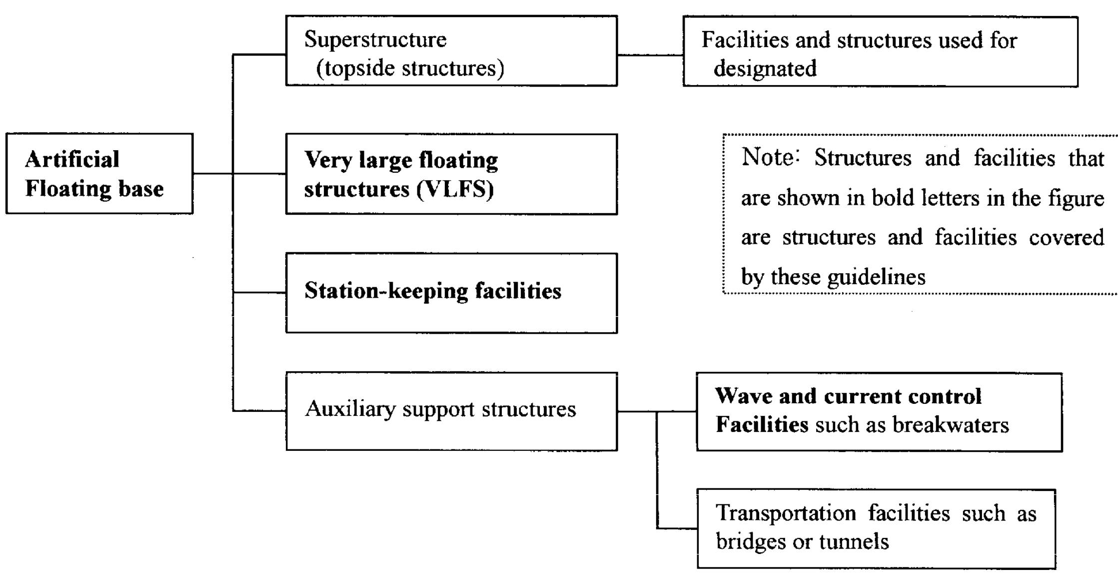

Fig.3 Diagram showing the structures and facilities that constitute artificial floating bases

(2) Objectives

Artificial floating bases are engineered structures, and therefore must be appropriately planned, designed and constructed, and appropriately maintained over their service lifetime. Moreover, regardless of the purposes for which they will be used, they are structures of tremendous size supporting facilities or structures that will be used by unspecified large numbers of individuals. In light of these characteristics, it was decided that the guidelines should have the following objectives.

(a) Safety of the lives of individuals at artificial floating bases

(b) Structural preservation of the components that make up artificial floating bases

(c) Preservation of the environment of the ocean zone where artificial floating bases are stationed

(3) Structures to which the guidelines will apply

The guidelines will apply to the floating structures and station-keeping facilities that will comprise artificial floating bases. When considering the safety of the artificial floating structure's organization, moreover, the presence or absence of wave and current control facilities, such as breakwaters that function to ensure calm in the ocean zones where artificial floating bases are located, will considerably influence the creation of critical natural environment conditions.

(4) Basic considerations regarding safety

The guidelines outline the basic thinking with regard to the objectives of "safety of human lives", "environmental preservation" and "structural preservation". Because maintaining safety during the period of service for artificial floating structures is important, it was also decided that the guidelines should also describe the management and safety system responses (maintenance management systems and disaster prevention systems).

(a) Safety of human lives

As the fundamental safety objective with regard to the safety of human lives the guidelines provide for appropriately undertaking preventive measures to avoid life-threatening phenomenon before they occur, measures for protection and evacuation from life-threatening situations such as accidents, and support measures to assist evacuated individuals.

(b) Preservation of the environment

The most important consideration is from the standpoint of environmental preservation to ensure floating structures do not pollute the ocean. These guidelines do not address this point, however, because this is covered by the Law Relating to the Prevention of Marine Pollution and Maritime Disaster (1970, Law Number 136). guidelines regarding the effect of the presence of artificial floating structures on the natural environment are to prepare means to suitably evaluate and observe the effects of the structures and to enact appropriate measures in response to such evaluation and observation results.

(c) Structural preservation

The fundamental safety objectives with regard to structural preservation are to ensure the ability of artificial floating structures to withstand the natural environment of the offshore ocean zones in which they are placed, ensuring structures do not suffer catastrophic damage (sinking of an artificial floating structure, drifting, etc.) even in the event of a natural phenomena or accident that rarely occurs, and ensuring that catastrophic damage does not occur in the event part of the structural functions are lost for any reason

(5) Assessment and Evaluation

Although the entities that implement an artificial floating base project will carry out the planning, design and construction of the floating structure based upon these safety standards, evaluations to determine whether or not the safety objectives have been achieved will have to be conducted objectively by a third-party. The guidelines therefore recommend that appropriate investigations with regard to safety should be carried out by the national government or institutions approved by the government. The results of all investigations should be made available to the public.

3.2.2 Chapter 2 Environmental impact assessment

There is a possibility that artificial floating bases will effect their surrounding natural environment because the floating structures that comprise floating artificial bases will occupy a fixed offshore ocean zone for an extended period of time and because of their vast size compared with that of existing ocean-based structures. Although environmental impact assessments conducted for uses such as landfills, airports, and electric power stations are regulated by the Environmental Impact Assessment Law (1997, Law Number 18), nothing is mentioned in that regulation with regard to floating structures. Conducting some form of environmental impact assessment for floating structures as well, therefore, will also be important. Based upon the fundamental ideas of the Environmental Impact Assessment Law, the guidelines call for environmental impact assessments to be developed specifically for floating structures.

3.2.3 Chapter 3 Materials

The principal construction of floating structures or station-keeping facilities will involve components made of steel or concrete. To ensure safety, these materials will have to meet a specified level of performance. The standards proposals recommend that the designated functions that are required for safety purposes should be verified experimentally and that certificates demonstrating that the experimental results are sufficient should be required.

3.2.4 Chapter 4 Design loads

In order to verify the organizational safety of floating structures or station-keeping facilities, the guidelines outline an approach for calculating the loads that will operate on the structures. It was decided to classify the different types of loads in the guidelines into accident loads from sudden collision by a vessel, or a fire, fixed loads, surcharge, and environmental loads. Furthermore, environmental loads are classified into three categories according to type and frequency: those that always occur (regular environmental conditions), those assumed to occur once during the service lifetime of an artificial floating base (maximum environmental condition) and extraordinarily extreme loads considered unlikely to occur during the normal course of the service lifetime of an artificial floating base (extraordinary environmental condition). These loads are then suitably combined in a manner making it possible to verify in detail the safety of the structures. In addition, specific calculation procedures taking the TRAM research results into consideration are described in the technology standards proposal.

3.2.5 Chapter 5 Floating structures

With regard to the structural safety of floating structures, it was decided that the guidelines should call for an approach that can be used to verify that structures will not sink and that life-threatening damage will not occur. In order to avoid the danger of sinking, the guidelines adopted an approach using bulkheads that expands on the approach used for vessels. This alternative calls for the use of watertight bulkheads to ensure a floating structures' upper section will not sink below the water line in the event water invades a compartment and to ensure the water will not spread from flooded compartments to other compartments. Because floating structures that will be subject to these guidelines proposals are extremely thin structures and cannot be evaluated using the structural analysis procedures normally applied to vessels or existing sea-based structures, it was decided that the guidelines should describe appropriate structure analyses to be carried out. The guidelines describe procedures for evaluations of structural strength to be appropriately combined with loads and the satisfaction of the requirements on structural preservation (3.2.1(4)(c)) confirmed. In addition, since the service periods for floating structures are long, the proposals also describe countermeasures for preventing structural deterioration.

3.2.6 Chapter 6 Station-keeping facilities

Station-keeping facilities are critically important facilities the primary function of which is to prevent floating structures from drifting. Normally the positioning of floating structures will be controlled through the use of multiple station-keeping facilities. Because there will be restrictions on the station-keeping facility placement or shape depending upon the use of topside structures, the number and shape of station-keeping facilities are also described as part of the structure's safety.

3.2.7 Chapter 7 Wave and current control facilities

The structural safety of wave and current control facilities such as breakwaters will be based upon laws and regulations that concern technology-based standards for ports and harbors. Because the function of is wave and current control facilities to ensure calm within the ocean zone where artificial floating structures are stationed, these guidelines describe only those measures required to verify this function.

3.2.8 Chapter 8 Disaster countermeasures

It was decided to outline provisions in response to the need to ensure the safety of human lives. In addition, it was assumed that life-threatening disasters such as the sinking or drifting of floating structures would not occur because the artificial floating base would conform to the provisions described in Chapter 4 through Chapter 6. As a basic disaster countermeasure policy, the safety of human lives will be ensured by considering the use and placement of topside structures, the creation of disaster prevention plans, and the use of management systems to control artificial floating structure disasters. As a disaster prevention designs, measures to reduce the causes of disasters, prevent disasters from spreading, provide for evacuation away from disaster areas and accommodate large numbers of evacuees are outlined.

3.2.9 Chapter 9 Construction quality control

Floating structures and station-keeping facilities are engineered structures. Maintaining the quality of construction is critical. This includes ensuring that adequate consideration is given to such things as checking that structural strength are provided according to plan. The proposals describe actions to ensure construction quality by establishing construction plans and inspection plans and implementing inspections and examinations according to these plans.

3.2.10 Chapter 10 Maintenance

Artificial floating structures will be used for multiple purposes over long periods of time. Maintenance management will be critical to ensuring the safety of such structures during their service lifetime. Like their counterparts in buildings on land, individuals working in the separate topside structures will be responsible for various aspects of maintenance management. Nevertheless, it is possible that improper or inadequate maintenance management in parts of the topside structures could be connected to improper or inadequate maintenance management for the entire artificial floating structure. Therefore, the guidelines describe actions for managers of artificial floating bases to establish a maintenance management system for the entire artificial floating base and undertake maintenance management in accordance with both the plans and the intent of maintenance management.

3.2.11 Chapter 11 Overall assessment

An artificial floating base is an integrated structural system that consists of a floating structure, station-keeping facilities, topside structures, wave and current control facilities, and transportation facilities. The safety of the floating structure or the station-keeping facilities alone can be verified through the provisions outlined in the preceding chapters. In chapter 11, requirements are provided for the purpose of verifying safety of the structure and accompanying facilities as an integrated structural system. As a basic approach a situation is assumed in which the effect of partial damage to the integrated structural system – such as waves that exceed established wave conditions acting on the floating structure because of damage to the wave and current control facilities – exerts a large effect on the safety of the floating structure or station-keeping facilities. The floating structure or station-keeping facilities do not suffer catastrophic damage even in the event of such cases. Based on the assumed scenarios, the proposals describe what is required to evaluate the likelihood of a worst-case damage situation such as the drifting or sinking of a floating structure and the extent of the harm (damage) from injury to the structure.

CONCLUSION

The guidelines for VLFS have been prepared as a comprehensive survey of the research results compiled over a three-year period.

These guidelines outline the basic ideas regarding safety and take into consideration the particular characteristics of very large floating ocean structures. These guidelines are concerned not only with standards regarding the safety of a VLFS itself and its moorage but also contain necessary details related to VLFS, such as evaluation of the environmental impact from the location of breakwaters and VLFS, disaster prevention countermeasures, and construction quality control. Although the contents are not as comprehensive as necessary in some areas, they are the first of their kind in Japan to bring together in a general proposal safety considerations with regard to the safety of VLFS.

Although these guidelines provide the minimum necessary details at the present time, it will undoubtedly be necessary in the future to supplement these standards proposals with knowledge acquired through advances in technology or experience with their application to actual structures, thereby moving closer to true safety standards through constant revision. In addition, these guidelines are expected to be put to practical application as the base standards when safety examinations are conducted by the Japanese government in the future.

In closing we would like to express our sincere appreciation to all of the individuals in the Maritime Technology and Safety Bureau and the Ports and Harbors Bureau at Japan's Ministry of Transport who provided advice and support from the standpoint of evaluating the safety of VLFS, the members of the Safety Standards Investigation Committee, the Specialist Sub-Committee, the enlarged Management Committee, and each of the Working Groups who held many stimulating discussions to debate the content of these safety guidelines and who provided valuable guidance and opinions based upon their extensive specialized information, and all of the individuals from the Technology Sub-committee of the TRAM who continue to reflect the VLFS experimental research results in their work while providing unflagging energy and enthusiasm in the creation of the basic proposals used to create these safety guidelines.